

High Definition Media Storage Structure and Playback mechanism

FIELD OF THE INVENTION

5 The present invention relates to high definition media storage structures and playback mechanisms.

BACKGROUND OF THE INVENTION

10 The present application claims priority on co-pending commonly assigned provisional patent application Serial No. 60/127,394, to Mercier, filed on April 1, 1999, entitled "High Definition Digital Video Disc Format", the contents of which are incorporated by reference herein.

15 Mechanisms for storage and processing of digital content on various media have been defined for various digital content playback systems. Recently, the resolution of digital content has increased. This content is now referred to as high definition digital content (HDDC). Current storage structures and playback mechanisms were not designed specifically for HDDC. There is a need for new storage structures and playback mechanisms for HDDC that introduce as little impact on current storage structures and play back mechanisms as possible. These new
20 storage structures and playback mechanisms will preferably support methods to prevent unauthorized access to the HDDC and to track any unauthorized access to HDDC. It is also desired that these new structures and playback mechanisms will support trick playback modes. The present invention broadly relates to and provides

a solution to these problems.

While the description which follows may sometimes be described in the context of audio/video/data as an example of content, the invention is not so limited and may equally apply to any type of information or content data, including without limitation audio and/or video data or other type of data or executables.

The invention is described in terms of the current best mode. This best mode is described as extensions of the DVD Specifications for Read-Only Disc (described in "DVD Specifications for Read-Only Disc", Version 1.1, December 1997 by Toshiba Corporation) to support high resolution, encrypted and actively watermarked content. Media conforming to these extensions are referred to in this document as HD-DVD. Playback mechanisms which present the HDDC content to an ATSC/HDTV compatible receiver are also disclosed. These mechanism allow graphics, trick modes, and watermarking to be extended to HDTV. One skilled in the art can see that although the present invention is described in terms of HD-DVD, the invention may be practiced on any digital storage media including hard disks, magnetic tape, and other optical discs.

The present application is directed to the same general technology as co-pending commonly assigned patent application Serial No. PCT/US00/00079, entitled "Content Packet Distribution" naming Schumann et al. as inventors (the contents of which are incorporated by reference herein). This application is directed more to specific storage structures and playback mechanisms including watermark insertion, trick modes, and ATSC stream generation.

In some commercial applications, where the content includes, for example,

valuable audio or video content, unauthorized access by those who obtain the content may tend to reduce the profit margin of the content provider(s), who typically provide the content, e.g. to various listener and/or viewers, for a fee. In particular, with the advent of high definition video, this problem is even more serious because the digital data is of sufficient resolution to be shown on a full size theater screen. This opens up a whole new area for content pirates to market their stolen property. If the unauthorized accessor is a content pirate, he or she may pose a serious threat to a content provider by inducing others to pirate the content as well. More particularly, the pirate may generally sell pirated access to the content at a lower cost than the legitimate content provider because the pirate obtains access to the content by using the legitimate provider's infrastructure and therefore does not have to invest resources to produce and disseminate the content. This becomes even a greater concern where the pirate may copy and mass produce a relatively inexpensive component which allows a large number of users to obtain access to the content without authorization by the legitimate content provider. As a result, content providers have resorted to increasingly expensive and complex schemes to prevent unauthorized access to their information and content, i.e. to prevent pirating.

What is needed is a system and method for protecting valuable content; a method and system which is robust, which may be tailored to the needs of a particular content provider, and which overcomes the above noted deficiencies.

SUMMARY AND ADVANTAGES OF THE INVENTION

One advantage of the invention is that it allows a disc to be authored where the

disc may be played by both conventional media players and high definition media players.

Another advantage of this invention is that elementary streams may be multiplexed and processed in the high definition media player instead of at authoring
5 time.

Yet a further advantage of this invention is that it provides for extended real-time features such as inserting watermarks into the content stream, decrypting selected sections of the content stream, and performing trick modes.

To achieve the foregoing and other advantages, in accordance with all of the
10 invention as embodied and broadly described herein, an apparatus for playing high definition content comprising a media player for receiving the high definition content from a media source. The high definition content is contained in data packets and the data packets are contained in sectors. A content processor processes the high definition content into transport packets and a transport packet modulator modulates
15 the transport packets. A controller manages the operations of the apparatus.

In yet a further aspect of the invention, the apparatus for playing high definition content further includes a watermark buffer for receiving watermark data; a video buffer for receiving video data; an audio buffer for receiving audio data; a watermark inserter for inserting watermarks into the video data, determined by the video data
20 and watermark data; a content multiplexer; and a transport packet generator.

In yet a further aspect of the invention, preselected bocks of the data packets are encrypted.

In yet a further aspect of the invention, the apparatus further includes a trick mode processor that can: create a slow motion effect by inserting empty predictive frames into a video elementary stream between picture frames; create a pause effect by iteratively inserting into the video elementary stream a sequence comprising an Intra-coded picture frame; and a multitude of predictive frames; create a fast forward playback effect by inserting forwardly sequenced Intra-coded picture frames interspersed with empty predictive frames into the transport packet stream; and create a rewind playback effect by inserting reverse sequenced Intra-coded picture frames interspersed with empty predictive frames into the transport packet stream.

In a further aspect of the invention, a method for playing high definition content comprising: receiving the high definition content from a media source, the high definition content contained in data packets and the data packets contained in sectors; processing the high definition content into transport packets; modulating the transport packets; and outputting the modulated transport packets.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawing, which are incorporated in and form a part of the

specification, illustrate an embodiment of the present invention and, together with the description, serves to explain the principles of the invention.

Figure 1 is a block diagram of a high definition content authoring system.

Figure 2 is a block diagram of an embodiment of an aspect of the present
5 invention used to playback high definition content.

Figure 3A is a block diagram showing an example of a video data packing
format.

Figure 3B is a block diagram showing an example of a video data packing
format header.

10 Figure 3C is a block diagram showing another example of a video data packing
format header.

Figure 4 is a diagram depicting timestamp calculations from a video bit stream.

Figure 5 is a block diagram of an ATSC transport packet.

15 Figure 6 is a block diagram showing how video access unit data may be
encrypted as per an embodiment of the invention.

Figure 7 is a block diagram showing alignment of encrypted data in the
transport payload as per an embodiment of the invention.

Figure 8 is a block diagram of watermark sectors as performed by some
current non-HD systems.

20 Figure 9 is a block diagram of HD watermark sectors as performed by an
exemplary aspect of the present invention.

Figure 10A is a block diagram of an exemplary aspect of the present invention
depicting watermark markers in a frame of video data.

Figure 10B is a block diagram of an exemplary aspect of the present invention depicting a watermark marker structure.

Figure 11 is a block diagram of an exemplary aspect of the present invention depicting a content processor.

5 Figure 12 is a block diagram showing trick mode processing.

Figure 13 is a block diagram showing how the slow motion playback trick mode can be obtained by inserting empty B pictures.

Figure 14 is a block diagram showing data flow through an embodiment of the present invention.

10 Figure 15 is a block diagram showing an embodiment of the present invention wherein watermarks are inserted into the content in the HDTV.

DETAILED DESCRIPTION OF THE INVENTION

15 The present invention provides for storing high definition content on a DVD or other storage media by extending the current specification of DVD read-only disc. The global disc layout may remain identical, preserving software investments for DVD authoring tools & player firmware, but higher video resolution and bit rates are allowed. HD-DVD players may not need any MPEG-2 video or AC-3 audio decoders, but may use instead a real-time content processor **214** and a modulator **216**. This
20 invention also provides for various "trick modes", including fast forward, reverse, slow motion, and pause. Also provided for are mechanisms that may allow the content to be encrypted and watermarked.

Encryption may be done on video, audio or other elementary streams during authoring, and may be based on blocks of consecutive bytes. Alignment methods ensures the mapping of encrypted blocks to the payload of a transport packet, and some rules define the conditions under which a block may or may not be encrypted, and where an encrypted block has to start. The transmission of watermarks in encrypted format to the TV receiver follows a buffering method and individual watermarks may be grouped in time stamped access units. Trick modes are also possible by slightly altering the content of video access unit headers and by inserting or suppressing MPEG-2 video frames. Finally, backward compatibility of the new system is possible if the audio and video formats of the classic DVD are supported by the ATSC standard (AC-3 audio, MPEG-2 video). MPEG graphics may also be supported.

Reference will now be made in detail to the presently preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings.

A block diagram of a high definition content authoring system is shown in Figure 1. Authoring systems are used to create the final image of the digital content in a format compatible with the intended display system. Time stamped elementary input streams **100**, including audio and video input streams formatted as MPEG-2 video and AC3 audio respectively, may be multiplexed together by the authoring tool **102** as they would be with a classic DVD, including data for multiple angles and parental levels. The authoring tool **102** is in charge of creating system files for Video Manager and Video Title Sets, one or more MPEG-2 program stream including navigation packs (Video Objects), and storing them as a disc or set of discs **104**. In

the presently illustrated embodiment, the discs **104** may be UDF formatted.

Figure 2 is a block diagram of an embodiment of an aspect of the present invention used to playback high definition content. The disc(s) **200** containing authored content may be inserted in a HD-DVD enabled player **210**. The player has a media player **212** that process the DVD specifications and extensions logic **220** that process the HD-DVD extensions. Together, the media player logic **212** and extensions logic **220** interpret the contents of the disc(s) **200** to create a combination of graphic menus and audio/video streams.

An embodiment of the present invention may include a secure session module **218**, so that secured communication may be established with the receiver before content playback may be authorized.

To send data to the receiver, the program streams stored on the disc **200**, or generated by an MPEG graphic engine are converted to an ATSC/HDTV transport stream by the content processor **214**. The stream is then modulated by a modulator **216** and sent to an HDTV receiver **224**. The present embodiment used 8-VSB modulation, however, any type of modulation capable of transporting the digital content may be used.

The receiver **224** demodulates the signal and reconstructs the transport stream packets, which are sent to their intended destinations which may include a decryption encoder **226**, audio and video decoders, or watermark logic **228**.

DVD Read Only vs. HD-DVD specifications.

The HD-DVD extensions may closely follow the DVD Specifications for Read-Only Disc, may enlarge the range of video formats allowed and may allow higher data rates on the disc. In the embodiment of the present invention, wherein compatibility with the ATSC/HDTV standard is desired, only those video and audio formats defined in the ATSC/HDTV standard may be used when the HD-DVD contains high definition material intended for HDTV display. The term 'HD mode' refers to when the HD-DVD player plays a disc with features not found in the DVD specifications for Read-Only disc.

A detailed description of the new parameter boundaries and constraints may be defined, in particular in the interleaved units minimum jump sizes that a HD-DVD player has to meet for multi-angle blocks. Areas that that may be extended for HD-DVD includes: parts of the video objects such as the contents of VOB, the player reference model, the presentation video, audio and sub-picture unit data; restrictions for seamless play; restrictions of SP_DCCMDs; relation between Information in disc and player; display mode; position and allowed line number's range of video and sub-picture; and karaoke mode in MPEG-2 audio.

In HD mode, the MPEG-2 video and audio configuration (i.e. bit rate, profile, level, AC3 for audio) may need to meet the ATSC/HDTV standard requirements.

Audio and video streams stored as an MPEG-2 program stream on the disc may be converted to an ATSC/HDTV compliant transport stream by the Content processor

Audio & Video demultiplexing

Extracting audio and video access units may be performed by extracting the payload of each corresponding packet. A start code search may be done to find each access unit's boundaries, unless pointers are added on the disc as private data. As shown in figure 3A, each MPEG video access unit (VAU) **300** may include a header **301** and slice data **302**, where headers may comprise one of the two descriptions as illustrated in figures 3B and 3C.

Figure 3B is a block diagram showing an example of a video data packing format header **310** which may include a sequence header **311**, sequence extensions **312**, GOP (group of picture) headers **313**, picture headers **314** and picture extensions **315**.

Figure 3C is a block diagram showing another example of a video data packing format header **330** which may include a picture header **331** and a picture extensions **332**.

An AC3 audio frame may start with a sync word 0xB77 and be encoded at constant bit rate, which makes frame extraction quicker.

Timing constraints

Timestamps include several components including a Tref, a Decoding Time Stamp (DTS), and a Presentation Time Stamp (PTS). The DTS represents the time to decompress the frame. The PTS represents the the time to present the frame. Tref is a temporal reference number. Obtaining a time stamp for each MPEG video access unit (PTS and DTS) can be done during VAU extraction, by using the PTS and DTS fields found in PES packet headers of DVD sectors. Only I frames are required

to have PTS and DTS. Time stamps for other pictures can be computed, but at the expense of extra memory to store data until the next reference frame (the DTS of a reference frame should be equal to the PTS of the previous reference frame). Time stamps may also be inserted at DVD authoring time to reduce memory requirements

5 in the player.

An example of DTS and PTS computation from a video bit stream, when only the first PTS and DTS are known is illustrated in figure 4. Timestamps **400**, **401**, **402**, **403** and **404** represent a sequence of timestamps. Timestamp **400** corresponds to an I frame. Timestamp **403** corresponds to a P frame which is derived from an I frame.

10 Timestamps **401**, **402** and **404** correspond to B frames which may be derived by either P frames, I frames, or both.

AC3 audio streams may be encoded at constant bit rate, in which case the PTS can be computed by linear extrapolation.

Multiplexing streams

15 A novel aspect of the present invention is that the transport multiplexing module may run independently in the player. Previous art usually performs this task in the authoring tool. In the presently illustrated example, there are three inputs: a video stream, an audio stream, and private data streams, each access unit being sent with a corresponding set of time stamps. In movie play mode, the streams are

20 multiplexed according the MPEG-2 specifications, the private data stream following a buffer model similar to the audio stream. The timestamped private stream may be used to assist in watermarking the content at runtime using a corresponding watermark access unit.

In MPEG graphics mode, the background is sent as an I frame and picture elements are added using P frames. Techniques similar to trick mode play may be used to build a valid, time stamped, MPEG-2 elementary stream that may be sent to the transport multiplexing module.

5 Any DVD authored according to the DVD Specifications for Read Only Disc with video and audio format supported by the ATSC (MPEG-2 video and AC3 audio) may offer a valid input for the transport multiplexer **214** and may be sent to an ATSC compliant HDTV through an 8-VSB interface **222**.

Storage, format and procedures to handle encrypted content.

10 Another novel feature of the present invention is that it allows content to be independently encrypted on a block by block basis. The DVD storage format is based on 2048 bytes per logical sector. This format is only used for storage, and the transmission of data may be done with ATSC transport packets of 188 bytes:

Figure 5 is a block diagram of a 188 byte ATSC transport packet **500**. The
15 Transport packet **500** may include a 4 byte header **501**, an adaption field **502**, and a payload **503**. When a packet has no adaptation field **502**, the payload **503** may have a size of 184 bytes. When an adaptation field **502** is present, to carry a PCR or padding bytes for example, the number of bytes of the payload **503** may be reduced accordingly.

20 Figure 6 is a block diagram showing how video access unit data may be encrypted as per an embodiment of the invention. To allow a real-time conversion from a time stamped MPEG-2 video stream and a time stamped AC3 audio stream to a valid transport stream, some fields in the headers **601** may have to be read and/or

modified. For this reason, they may not be encrypted. In a video access unit the encryption may start on the first 184 byte block **606** completely contained in the slice data area **602**, continue through blocks **607**, **608**, **609**, **610**, **611**, **612** and stop on the last 184 byte block **613** completely contained in the slice data area. Not all of these
5 blocks have to be encrypted, but no other blocks may be encrypted in the video stream. Therefore, blocks **603**, **604**, **605** and **614** are not encrypted.

Audio streams can be encrypted in a less restrictive manner, since the size of an access unit can be predicted. For example, only 1 out of 10 audio access units can be left unencrypted.

10 A major problem with encryption of elementary streams is to avoid any misalignment between elementary stream encrypted data and transport streams packet decryption. Figure 7 is a block diagram showing alignment of encrypted data in the transport payload as per an embodiment of the invention. Transport packet **700** contains a 4-byte header **701**, alignment padding bytes **702**, and payload bytes **703**.

15 The second transport packet **710**, includes a 4 byte header **711** and 184 bytes of encrypted payload data **712**. A solution to this problem, if it occurs, is to insert padding bytes **702** in the last packet **700** preceding a group of encrypted packet **710** to ensure the correct alignment of the 184 bytes of the transport packet payload **712** (a transport packet cannot contain both encrypted and unencrypted data). If the data
20 is encrypted as previously described, then only one padding operation is required, in the last packet preceding the blocks of encrypted slice data. When an adaptation field must be sent during the transmission of encrypted packets, to transmit PCR for example, then an extra transport packet may be inserted with an adaptation field but

no payload at all, in order to preserve the encryption alignment.

A method to signal in each frame which 184 bytes block is encrypted, and which one is not is now described. A header made of a few bytes in each DVD sector is used. One byte indicates the number of bytes in the payload before the beginning
5 of the first 184 byte block. Then 11 groups of 2 bits may be used to store the MPEG-2 transport scrambling control field. One bit indicates if the sector contains any encrypted data. A total of 31 bits may be required. Those bits may be stored over an unused DVD sector packet header field, like SCR, when the VOBS has encrypted content. Another option may be to simply encrypt all data, and set a flag in a global
10 header.

In summary, video elementary stream may be partitioned in blocks of 184 consecutive bytes, and each of these blocks which only contain slice data and only slice data can be encrypted. To restore the alignment of these blocks with the payload of a transport packet, padding bytes may be used in the adaptation field of
15 the transport packet preceding an encrypted transport packet. To preserve the alignment of the payload when an adaptation field is required, an extra packet with no payload may be inserted.

Allowing the occasional insertion of padding bytes and packets without payload, the bit rate of the video elementary stream may be carefully adjusted to
20 avoid any video buffer overflow. This constraint may be combined with the bandwidth requirements of watermark information.

Watermarking support.

An example of current watermark technology is illustrated in figure 8.

Watermark sectors **800** are performed on this non-HD systems by inserting private sectors **801** at authoring time to store watermark information (mainly replacement data and location for each watermark). The location of a watermark is identified by 3 parameters: A physical sector number **802**, an offset in the sector **803**, and the length in bytes **804**. When a sector **831**, **832**, and **833** is received from data on the disc **830**, the sector number is compared with those in the watermark table and if a replacement is required, replacement data **805** is written into the sector **832** at the location indicated by the offset.

Referring to figures 9, 10A, and 10B, we will now discuss the aspect of the present invention that implements content watermarking. Figure 9 is a block diagram of HD running sectors as performed by an exemplary aspect of the present invention where watermark technology may be preserved by only changing location information of the watermarks. Figure 10B is a block diagram of an exemplary aspect of the present invention depicting a watermark marker structure.

In the HD-DVD context, the receiver is in charge of inserting watermarks and has no knowledge of DVD physical sectors. A solution to this problem is to assign an identifier to each watermark and insert the identifier in the video where the watermark must be inserted as illustrated in figure 10. In figure 10A, markers **1002**, **1004**, and **1006** are inserted in the video content **1000** where a watermark is intended to be written. The markers **1050** includes a start code **1052** and a watermark ID **1054**. One skilled in the art will recognize that many different marking schemes may be used to indicate locations for watermark insertions.

As presently illustrated, the current embodiment uses an 8 byte watermark that

is overwritten. The ID **1052** may be a 4 byte long watermark start code such as 0x000001BA. The sequence number **1054** may be a 4 byte unique watermark identifier, WMID **920**. The watermark sector number **802** and offset **803** used in the prior art are replaced by the WMID **920** in the watermark sector. The original 8 bytes of data may be saved in the watermark sector and the PTS of the picture to which the watermark applies allows the transport stream multiplexer **214** to send the watermark data in real-time. For example, the WMID **920** may be an incrementing counter starting at 0x0200 to avoid generating start codes.

An alternative method would to use the WMID/offset **920** as an offset into the frame. This method would not require any markers in the video data.

As described above, the watermarks are stored in HD watermark sectors **900**. A group of watermarks with the same PTS **922** may be referred as a watermark access unit and may be stored in the same physical sector. This access unit may follow a watermark buffering model, which may be described with a leak rate and buffer size that may be defined depending on the bandwidth allowed for watermarks (This buffering model is described the MPEG-2 standard). The transport multiplexer **214** may ensure that each access unit arrives in time in the watermark buffer.

When a picture is received and watermarks have to be inserted, the picture may be scanned for the watermark start codes which are followed by the WMID **920**.

The watermark buffer **910** has the corresponding WMID **920** information to either restore the original 8 bytes **924** (start code and WMID) or to insert the replacement data **928**. The size of the replacement data **926** may be stored as part of the watermark buffer **910**. If the corresponding WMID **920** is not in the buffer, then a

pirate attack is very likely to have occurred. The TV may decide to wait a few seconds and turn the screen dark, refusing content playback.

If the start code search method is too demanding in CPU resources in the TV, an offset from the first byte of the slice data could indicate the location of each watermark.

Encryption of watermarks may be done on a watermark access unit level. Watermarks belonging to the same frame (i.e. watermarks having the same PTS) may be grouped together in a more efficient manner to allow encryption: a watermark access unit header followed by watermark data. The header could be composed of the DTS, number of watermarks in the access unit, size in bytes, and would not be encrypted. The rest of the data could be encrypted and aligned by the transport multiplexer **214** with the same method that for video access units. Not encrypting the header should not compromise the security of the system since the WMID found in the picture at watermark insertion time must match the watermark data, and watermarks attacks can be detected.

Figure 11 is a block diagram of an exemplary aspect of the present invention depicting a content processor **1110** that is configured to input elementary streams, insert watermarks, perform trick mode display functions, multiplex audio and video content, and formats the resultant data into a valid output transport stream **1134** such as ATSC for output. The elementary streams include watermarking packets **1100**, video packets **1102**, and audio packets **1104**. The watermarking packets are input into a watermarking buffer **1120**. A watermark inserter **1126** inputs watermark sectors from the watermark buffer **1120** and inserts watermarks into the video data stored in a

first video buffer **1122** for output into a second video buffer **1128** using watermarking techniques that were discussed previously. The video packets **1102** are input into a first video buffer **1122**. The data is then transferred into a second video buffer **1128** where the video data is combined with watermarks. Next, the data stored in the second video buffer **1128** may be input to a trick mode processor **1130** where output display trick modes may be performed on the video streams. The audio packets **1104** are input into an audio buffer **1124**. Data processed by the trick mode processor **1130** and the audio buffer **1124** are both input into a content multiplexer **1132** which combines the data into a combined data stream. The combined data stream is then input into a transport packet generator **1134**, which formats the data into a transport packet stream **1140** such as ATSC. One skilled in the art will recognize that a content processor could be built to handle other types of data instead of or in combination with the watermark, video and audio data types discussed here.

Figure 15 shows a block diagram of another embodiment of the present invention demonstrating how video watermark insertion may occur in an HDTV **1520**. As illustrated, the content is contained on a media **1500**. The content is read and processed by an HD player **1510** which produces a transport stream such as ATSC and modulated using a modulation scheme such as 8-VSB, containing processed content for display. The processed content is input into the HDTV, where it may be decrypted and demultiplexed by a decrypter/demultiplexer device **1530**. Next the data is stored into buffers. In this example, the timestamped watermark elementary stream is buffered in a timestamped watermark elementary stream buffer **1532**. The timestamped video elementary stream is buffered in a timestamped video elementary

stream buffer **1534**. Both the buffered watermark and video data are input into a watermark inserter **1538** where watermarks are inserted into the video stream producing a watermarked video stream **1540** such as MPEG video. The watermarks are inserted when the timestamps (DTS/ PTS) match the current Video picture

5 DTS/PTS time stamps The watermarked video stream **1540** is then displayed as a decoded image **1542**.

One skilled in the art will appreciate that the concept of watermarking as presented may equally be applied to other types of data streams besides video, such as audio, executable or process data. Executable data may include programs

10 intended for execution on a target device such as a smart HDTV. Process data may include data or files that communicate information such as HTML or XML to a target device.

Trick modes

Trick modes modify the video stream to produce output display effects such as

15 pause, slow motion, fast forward and reverse. Traditionally, trick modes are generated directly by decompression chips. The present invention may generate trick modes altering the video stream before it is decoded. Figure 12 shows a video stream **1200** being input to a trick mode processor **1210**. The output of the trick mode processor **1210** is a modified video stream **1220** that may now be multiplexed with

20 other content streams before being converted into a stream of transport packets. The video frames are typically MPEG frames. MPEG frames include P frames, B frames and I frames. I frames, are video frames known as Intra-coded pictures (I-pictures). I frames are coded in such a way that they can be decoded without

knowing anything about other pictures in a video sequence. P frames, are video frames known as predictive coded pictures (P-pictures). P frames are decoded using information from another frame that was displayed earlier. B frames, are video frames known as bidirectionally predicted pictures (B-pictures). B frames are bi-directionally decoded using information from other frames. The other frames may occur before or after the B frame. P frames and B frames are often referred to as predictive frames. Trick modes may be achieved by extracting MPEG-2 video elementary frames using search algorithms. The frames may be converted to a valid MPEG-2 video elementary stream by adjusting headers, like the temporal reference fields of picture headers and by inserting empty P frames or empty B frames. An empty frame has null motion vectors, no residual data coded (coded block pattern is 0) and has the property of repeating the content of one of the reference frames. These techniques, along with a time stamp correction provides the possibility to generate a valid MPEG-2 elementary video stream with a valid number of frames per second (29.97 for NTSC for example). The impact on the content processor **214** is that it must continuously output the data stream. A stack of queued transport packets transferred in hardware by DMA may reduce the amount of CPU required.

Each picture header and PES (program elementary stream) header may be changed to reflect the insertion or deletion of pictures in the elementary video stream.

Because of the interdependency of I, P and B frames, some rules may need to be followed including: (1) any B frame may be suppressed or inserted; (2) a P frame may be suppressed only if all other frames dependent upon the suppressed P frame are also suppressed.

Figure 13 shows a sequence of frames where the first frame **1300** is a first original picture. Empty B frame(s) **1310** may be inserted into the video stream to create a slow motion or pause effect. Then a second original picture **1320** is input to the video stream. Fast forward and rewind playback may be obtained by playing back I frames and inserting empty B frames to adjust playback speed and control the bitrate.

Although the trick modes are described here in terms of MPEG-2 frames, one skilled in the art will recognize that the present invention may be practiced on other types of video that utilize predictive video frames.

Data Flow

Figure 14 is a block diagram that shows the data flow through an embodiment of the present invention during playback of high definition content with real-time conversion to a packet transport stream. The high definition digital content is authored and stored on storage media **1400**. An HD player **1410** may then read the content from the media **1400**. The content may be stored as audio, video, and data sectors **1420**. An example of a storage media may be a classic DVD disc, extended with High Definition Video formats and an example of a data sector type may be DVD sector. A media player **1430** may include a media reader and media reader logic. Data may be extracted from the sectors **1430** and demultiplexed into elementary streams including an elementary video stream **1440**, an elementary watermark stream **1442**, and an elementary audio stream **1444**. Timestamps may be included within the elementary data streams. These streams may be input to a content processor **1450** where they may be processed. Processes may include insertion of

watermarks, processing trick output display modes, multiplexing content streams, and transport packet generation. The output of the content processor **1450** may be transport packets such as ATSC transport packets. Content multiplexing may need to follow packet alignment methods to ensure valid decrypted elementary streams when the streams are encrypted. A modulator **1460** may modulate the output packets for transport to an HDTV **1470**. The HDTV may also perform functions on the content including demultiplexing the elementary streams, decoding the content, decrypting the content, watermarking the content and displaying the content.

The present invention provides extensions of media formats including DVD to high resolution video, while maintaining most of the current architectures. An added benefit of this invention is backward compatibility, although backward compatibility may be limited to some audio and video format. These HD-DVD extensions provide for encrypting content, watermarking content, and trick playback display modes.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. For example, it will be apparent to those of skill in the art that the content may be provided from any type of source device for processing and playback on other devices according to principles of the present invention. Therefore, unless such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.